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A Model for the Condensation of a Dusty Plasma

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A model for the condensation of a dusty plasma is constructed by considering the spherical shielding layers surrounding a dust grain test particle. Since the diameter of the shielding region is smaller than a collision mean free path, the shielding region can be considered as being a collisionless spherical region which is surrounded by an outer collisional region. This collisionless inner region is shown to separate into three concentric layers, each having distinct physics. A collisionless Vlasov model must be used for ions in the inner-most layer and it is shown that the resulting ion density is much smaller than the predictions of the Boltzmann relation which is shown to be inappropriate in this layer. The method of matched asymptotic expansions is used at the interfaces between the three collisionless layers to derive a pair of nonlinear equations which determine the radii of the two interfaces between the three collisionless layers. Despite being much smaller than the Wigner-Seitz radius, the dust Debye length is found to be physically significant because it gives the local scale length of a precipitous cut-off of the shielded electrostatic potential at the interface between the second and third collisionless layers. Condensation of a dusty plasma into a Coulomb crystal is predicted to occur when the ratio of this cut-off radius to the Wigner-Seitz radius exceeds unity and this prediction is shown to be in good agreement with published results from a number of different experiments.

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Observation of Microparticle Gyromotion in a Magnetized DC Glow Discharge Dusty Plasma*

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Laboratory observations of the motion of charged microparticles have been made in an argon dc glow discharge plasma created within a strong dc magnetic field. The experimental configuration consists of an anode-cathode pair centered between a pair of neodymium iron boride permanent magnets. The cylindrical axis of the resulting plasma column is directed vertically (i.e., along the direction of the gravitational force). Depending upon the orientation of the magnets, the magnetic field can be directed either upward or downward, with a field strength of approximately 2.5 kG. A pair of Helmholtz magnetic field coils external to the vacuum chamber allows the magnetic field to be varied by approximately ±75 G in the experimental region. Alumina microparticles (~1.2 μm) placed directly on the grounded cathode provide the source of charged dust in the plasma. Individual dust grains suspended in the plasma can be observed moving in an oscillatory fashion. Measurements of the oscillation frequency, spatial amplitude, and scalings with magnetic field strength and transverse particle velocity have been made. The measurements are consistent with the expected gyromotion of magnetized dust grains under the ambient plasma conditions and the data are shown to provide an effective method for the noninvasive determination of the dust grain charge.

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